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TOMATO DISEASES

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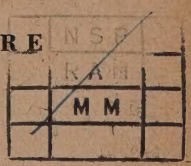

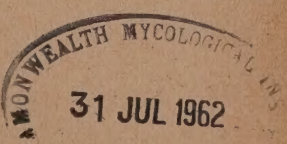

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TOMATO DISEASES

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PART 1

Introduction

Tomatoes are grown widely in Canada. There is hardly a garden that does not have a dozen or more plants. In suitable areas large acreages are grown for the fresh vegetable market and for processing. In Ontario the tomato is the most important vegetable crop grown for processing and outranks in value all other such crops combined. In British Columbia also it is the most valuable vegetable crop.

The tomato is a heat-loving plant and a soil-exhausting feeder; unless well supplied with plant food it will grow poorly and produce unsatisfactory crops. Therefore tomatoes should be planted only in soil with high fertility, good drainage, and high organic content. If earliness is desired, a fertile, sandy loam is preferable to a heavier soil.

A satisfactory crop of first-grade, sound tomatoes can be obtained only from well-nourished plants that are free from disease. Careful attention must be given to disease control as well as to culture. Both are essential. This bulletin should assist growers to avoid and overcome the many diseases that attack tomatoes.

Causes of Disease

Diseases are caused by parasitic fungi, bacteria, nematodes, and viruses, or they may result from unfavorable environmental conditions.

Fungi

Fungi are mostly microscopic plants that for their existence depend on other living plants or dead organic matter. Certain fungi attack crop plants and even weeds and thus cause disease. Fungi produce countless numbers of spores some of which are carried by wind or other means to their hosts and under favorable conditions of temperature and moisture germinate and infect healthy plants.

Bacteria

Bacteria are microscopic, single-celled plants that multiply by division of the parent plant into daughter plants. The single cells usually multiply at a rapid rate so that a single bacterium may give rise to 17 million of its kind every 24 hours.

Nematodes

Nematodes are small, usually microscopic, soil-inhabiting worms some of which enter the roots of plants (endoparasites) while others (ectoparasites)

feed on the roots from the outside. When either type is present in large numbers affected plants become unthrifty and their yields may be reduced. The root-knot nematode produces swellings or galls on the roots of tomatoes, tobacco, cucumbers, and many other plants.

Viruses

Viruses are the most minute entities that induce disease in plants. They are so small that they cannot be seen with the ordinary light microscope but their shape and size can be determined with the electron microscope which magnifies to 20,000 diameters or more. Virus diseases are diagnosed chiefly by their symptoms.

Environment

Some disorders are caused by environmental factors which may seriously affect normal growth. Such factors may be temperature or moisture above or below ground, unbalanced nutrition, deficiency or excess of minerals, acidity or alkalinity of the soil, poor drainage, industrial fumes or other factors.

General Information for Prevention of Disease

As a general precaution, seed should be treated, soil sterilized, seedlings sprayed, the use of tobacco avoided by workers, and certain sanitary measures practiced. These recommendations are especially important in the early life of the tomato plant.

Seed Treatment

Seed should be treated with hot water to destroy internal infections, and it should be protected against surface seed-borne organisms by a seed protectant.

The hot-water treatment requires special equipment and rigid control of the water temperature and obviously should be the responsibility of the seed producer rather than the grower. With the facilities at their disposal it is much more difficult for growers to treat small lots of seed satisfactorily. Nevertheless, the hot-water technique is outlined here for the information of growers.

The seed should be put in small cheesecloth bags, partially filled, and then immersed in hot water at 122°F for 25 minutes. After immersion, the seed should be dipped in cold water and then dried. The temperature of the water must be maintained at 122°F and this may be more readily accomplished if the volume of water is large in relation to the volume of seed. It is also essential that every seed be wetted during the treatment, hence the bags should be submerged and agitated for the full period.

Fungicidal Protectants

Whether or not the seed has been treated with hot water, all seed should be treated with a seed protectant. Thiram (Arasan), captan (Orthocide), dichlone (Phygon XL), Ceresan or chloranil (Spergon) are suitable for this purpose and should be used according to the directions on the package. Treat seed by placing the required amount of fungicide with the seed in a jar or bottle and stopper it tightly. If the bottle is less than half filled, the seed on being shaken will have a better chance of being covered with the fungicide. Any excess dust may be removed by shaking the seed on a fine sieve. After treatment, the seed may be sown directly or stored in a clean container until required.

Sowing of Seed

The treated seed should be sown in soil that has been sterilized with steam or chemicals. It is better if the flats are new, but if old ones have to be used, they also should be sterilized with steam or chemicals. The grower should realize that if treated seed is sown in infested soil, the value of the treatment may be lost because several diseases such as leaf spots, wilts, blights, damping-off, and mosaic may start in, and spread from, the soil in which the seed is sown.

It is better, too, to use sterilized soil for transplants, though new soil—that is, soil that has not grown tomatoes, potatoes, peppers, or other vegetables for several years—should be satisfactory.

Spraying of Seedlings

Spraying of seedlings should be started when the first true leaves have formed and should be repeated at 7- to 10-day intervals, with the last application 4 to 5 days before plants are set in the field. In most provinces, ziram or fixed coppers are used according to manufacturer's recommendations.

Sanitation

Regardless of the care taken in treating the seed and soil, results may be unsatisfactory if due attention is not given to certain sanitary measures.

Many weeds may be infected with certain tomato diseases, therefore weeds should not be tolerated in or near the seedbed or plant beds. Since many of the diseases affecting tomatoes may live over in old tomato plants and debris, such plants and debris should be burned.

General Information on Soil Sterilization

In greenhouses or cold frames where steam is available, soil may be sterilized by the following methods:

Inverted Pan Method

Steam, under pressure, is passed into an inverted pan which is forced into the ground. The pan may be of any convenient size though it is difficult to handle one larger than 70 sq. ft. in area. Before the steam is forced in, the pan should be weighted to keep it in the ground and thus prevent the escape of steam around the edges.

Drain Tile Method

This method is in general favor today, especially in greenhouses, even though the initial installation is somewhat expensive, because in the long run it is much more convenient and requires less labor. The tiles (3-inch ones are satisfactory) are laid in rows 15 to 20 in. apart, and 12 to 15 in. below the soil surface. Steam is passed into the tile through a header. In long greenhouses it will be necessary to divide the tiles into sections, and treat one area at a time.

Both the above methods are primarily suited to ground soil sterilization in greenhouses.

In benches, perforated pipes, such as downspouting, or perforated hose may be used with plastic sheets or tarpaulins to cover the bench and hold in the steam.

With any of these methods the soil must be in a loose moist condition. If the soil is too dry, steam will escape too freely, and if too wet, efficient penetration of the soil is not possible. Steam should be in sufficient volume and under sufficient pressure to maintain the soil temperature at 180°F. for half an hour or longer depending on the depth of the soil. In ground beds, the required temperature should be maintained to a depth of 12 to 15 in. and this will require sterilization for an hour, or longer. For lesser depths, as in seedbeds or benches, half an hour is generally sufficient. The important factor is that the temperature should be maintained at 180°F at the lowest depth for at least half an hour.

Sterilization with Chemicals

Where steam is not available satisfactory sterilization may be effected with chemicals. Formalin, chloropicrin, or methyl bromide (Dowfume MC 2) may be used.

Formalin (40 per cent formaldehyde)—When formalin is used, the soil should be in a loose, uniformly moist condition. Formalin should be used in the proportion of 1 gal. to 50 gal. of water, and at the rate of ½ to 1 gal. of the solution to every square foot of soil. After treatment, jute bags or papers that have been wet with the formalin solution should be placed over the soil for at least 48 hours, in order to retain the formaldehyde fumes in the soil. Thereafter the soil should be turned over and aerated at frequent intervals until the odor of formaldehyde can no longer be detected. Then it may be used for planting. This generally takes 2 to 3 weeks. This method is particularly adaptable to the small greenhouse and for treating soil in seedbeds or benches.

Chloropicrin (tear gas)—Whereas formalin is diluted with large quantities of water (1:50) and poured on the surface of the soil, chloropicrin is used at full strength, but in very small amounts placed several inches below the surface of the soil in holes 10 to 12 inches apart. Therefore a special injector is used to apply it. This instrument may be adjusted to give the correct amount of the chemical at the required depth. After treatment, the top 2 inches of the soil should be kept moist for 3 days by sprinkling it with water. The temperature of the soil should be between 60°F and 85°F for best results. Plants should not be placed in treated soil for at least 10 to 14 days, or until all traces of the gas have disappeared. Directions for using chloropicrin accompany all containers. Safety precautions should also be followed.

Dowfume MC 2 (98 per cent methyl bromide and 2 per cent chloropicrin)—Follow manufacturer's directions and recommended safety precautions carefully.

Warning

Fumes from the soil fumigants mentioned above are highly injurious to growing plants. The use of these fumigants is thus limited to greenhouses that are free from crops or to sections so airtight that fumes cannot spread to sections containing crop plants.

Operators should use respirators and wear protective clothing.

Sterilization of Small Quantities of Soil

Small quantities of soil may also be sterilized by steam or by chemicals. Where steam is used all that is necessary is to pass steam into the container holding the soil such as a box, or to pass steam into small piles of soil covered with plastic covers. A temperature of 180°F for at least 30 minutes is required.

Formalin at the rate of 2½ tablespoons diluted with 6 times as much water for each bushel of soil will give satisfactory sterilization. For larger quantities use 1 pint formalin to 6 gal. water, applying this solution at the rate of ½ gal. per cubic foot of soil. In either case, mix the formalin thoroughly with the soil then cover for at least 48 hours with plastic sheets, or paper bags, wet with formalin. Before using, aerate until the odor of formalin is no longer present.

Small quantities of soil may also be sterilized with thiram (Arasan) by *thoroughly* mixing the dry powder with soil at the rate of 1 oz. to each 10 cu. ft. of soil. The mixing can be done with a shovel or in a cement mixer. Chloropicrin or methyl bromide may also be used. Follow directions on the container.

Spraying Tomatoes in the Field

For many years growers paid little attention to controlling diseases of field tomatoes. It is only in recent years that spraying has become more or less an accepted practice. Because of this lack of control in past years and the resulting build-up of the causal organisms in the soil, certain diseases, especially anthracnose and blights, have increased in importance, so much so that spraying is now essential if crops of quality tomatoes are to be obtained every year.

Though some twenty-five different diseases may affect tomatoes, only early blight, leaf spot, anthracnose, late blight and mosaic or other virus diseases are important in most provinces. With the exception of the virus diseases parasitic diseases may be prevented or satisfactorily controlled by the spray schedules recommended in the different provinces.

Spraying of tomatoes in the field should be started in the first or second week of July and should be continued throughout the season at 10-day intervals. The number of applications required will depend on the season and growth of the plants. Maneb, ziram, zineb, fixed coppers, and bordeaux mixture are recommended in most provinces. If late blight develops, bordeaux is the best material to use and the later sprays are generally the most important ones. In British Columbia, however, zineb is preferred to bordeaux.

Growers should use the materials and schedules recommended by the authorities in their province.

PART 2

Fungus Diseases

Damping-off

This is primarily a seedbed trouble, caused by various soil-inhabiting fungi, especially species of *Rhizoctonia* and *Pythium.* The seedlings may be attacked either before or after they emerge. In the former case germination is reduced, and in the latter, plants wilt, fall over, and die. Occasionally entire beds may be destroyed, especially if untreated seed is planted in unsterilized soil.

Control measures are based on the fact that damping-off is caused by common soil-borne organisms.

(1) Seed should be given the hot water treatment and then treated with a fungicidal protectant such as thiram, captan, or Ceresan. The treated seed should be sown in sterilized soil.

(2) Avoid thick seeding. A crowded seedbed favors damping-off.

(3) The surface of the soil should not be continuously damp. Plants should be watered only when they are very dry, and preferably in the forenoon so that the surface of the soil will be dry by night.

(4) Good ventilation is an absolute necessity.

(5) If in spite of these precautions, damping-off develops, dust the plants lightly with thiram or a similar fungicide from a salt-cellar type of container, or water flats or seedbeds at the rate of 2 gal. per sq. yd. ($\frac{1}{2}$ gal. per flat) three times at four-day intervals with one of the following: thiram, 1 oz. per gal.; ferbam 1 oz. per 5 gal.; Ceresan, 1 oz. per 3 gal. Reduce watering.

Collar Rot

At least four different fungi are capable of causing a collar rot, either on seedlings or on more mature plants. Irrespective of the organism concerned, the disease appears as a canker or rot of the stalk at or just above the ground line (Fig. 1). When the stalk becomes girdled, the plant wilts and dies.

The fungi associated with collar rot in Ontario are *Sclerotinia sclerotiorum, Botrytis cinerea, Phytophthora parasitica, Alternaria solani* and *Rhizoctonia solani.* When *S. sclerotiorum* is present a white mycelial growth, with or without black sclerotia, may be found on the affected tissue, while *B. cinerea* may be identified by a gray moldy growth.

Control

(1) Remove infected plants.

(2) Where this disease has occurred in greenhouses the soil should be sterilized, and the greenhouse fumigated before planting the next crop of tomatoes.

Leaf Spot

Caused by *Septoria lycopersici* Speg.

Leaf spot causes numerous small, circular spots on the leaves, stems, petioles, and in severe cases, even on the fruit (Fig. 2). These spots are generally grayish in color, with a black border, although sometimes solid black spots are found. In the center of these spots, small black 'pimples', the fruiting bodies of the fungus, may be seen with the aid of a hand lens. The disease starts on the lower leaves and, under favorable conditions, progresses

upwards. Severely affected leaves turn yellow, dry up, and fall off. The damage to the crop is due largely to the reduction of the leaf surface, which in turn reduces the size and quality of the fruit.

In Ontario this disease is extremely common; in some localities however, it is not generally considered of economic importance, since it seldom becomes prevalent until late in the season. At this time, the damage to the crop is of much less importance than when the disease occurs on young plants early in the growing season. In the irrigated districts of British Columbia leaf spot is unknown.

Control

Since the leaf spot fungus lives over winter on dead tomato vines, it is essential that the refuse from a crop be destroyed by burning, or plowing under. In the greenhouse, all diseased leaves and tops should be carefully gathered and burned.

It is also essential to do more than practise strict sanitary measures. Since the leaf spot fungus is capable of living on such weeds as horse nettle, ground cherry, deadly nightshade, and jimson weed, these plants should not be tolerated in or near the seedbed, plant bed, glasshouse, or field where tomatoes are growing. Experience has shown that it is easier to control leaf spot when legumes and cereals are included in the crop rotation.

The recommended spray schedule should control this disease satisfactorily in most seasons.

Early Blight (Target Spot, Black Rot)

Caused by *Alternaria solani* (Ell. & Mart.) Jones & Grout

Early blight, like leaf spot, causes serious loss of leaves in some seasons. In fact these two diseases, either separately or in association, are responsible for most of the defoliation that occurs on tomatoes in Canada. Early blight also attacks the stems and fruit. On the leaves, circular, dark brown to black spots of various sizes are produced. The spots, often up to ½ inch in diameter, are readily recognized by the concentric rings or zonations, hence the name "target spot" (Fig. 3). When these spots occur around the margin of the leaf, their symmetric ringlike appearance is often lost in the uneven outline of the edge of the leaf. On the stalks, branches, and fruit pedicels, early blight appears as black lesions that subsequently enlarge and elongate and sometimes girdle them. These enlarged lesions are referred to as "collar rot" when they occur on the stalks near the ground, and as "stem canker" when they occur on the branches.

On the fruit, large, black, leathery sunken areas are produced. These generally start around the fruit pedicel or in some small wound or crack and enlarge in size. In the irrigated districts of British Columbia early blight does not affect tomatoes while they are growing in the field during the summer months. However the disease may occasionally cause leaf and fruit lesions during September and October following rainy periods.

Control

Control measures given above under leaf spot also apply to early blight.

Late Blight

Caused by *Phytophthora infestans* (Mont.) de Bary

This disease, although more prevalent on potatoes, infects tomatoes under favorable environmental conditions, particularly when they are near infected

potatoes. On the leaves late blight produces greenish brown, irregularly shaped, water-soaked spots with pale green margins (Fig. 6). Affected leaves wilt and die and during wet weather usually show a gray mold at the margin of the lesions on the under sides of the leaves. Brown cankers are often formed on the stems and leaf petioles and the fruit develops a firm, blotchy, greenish brown rot, which usually spreads from the stem end. The disease spreads rapidly during wet weather, especially if the days are warm and the nights cool. Severe losses may occur during transit and in storage.

Control

The spray schedule recommended in your province is essential for prevention and control of this important disease.

Leaf Mold, Brown Mold

Caused by *Cladosporium fulvum* Cooke

This is primarily a disease of tomatoes grown in greenhouses, though in some seasons it may attack field tomatoes, or seedlings in the plant bed.

The symptoms of this disease are yellowish green, indefinite areas on the upper surface of leaves accompanied by greenish brown moldy areas on the under side (Fig. 4). When the atmosphere is humid, the stems, blossoms and fruits, as well as the leaves, may be affected. On the fruit, a black stem end rot, often involving a considerable portion of the fruit is sometimes caused by this fungus. Because of the great profusion of spores produced by this fungus, spread takes place rapidly, especially in the warm humid atmosphere found in greenhouses.

Control

1. Several resistant varieties are available. Vulcan is recommended for the fall crop since it is resistant to most strains of the causal fungus. Vine-queen, a new variety developed by the Vineland Horticultural Station, is recommended on a trial basis for both fall and spring crops. This variety is resistant to the seven known pathogenic races of the causal fungus. Improved Bay State and Waltham Moldproof Forcing are satisfactory, especially for the spring crop.

2. Keep humidity as low as possible and yet sufficient for good growth. This may be accomplished by increasing the temperature and opening the ventilators, or by forcing out the warm humid air when the humidity of the intake air is low.

3. Water the plants at ground level and thus avoid unnecessary wetting on the leaves.

4. It is advisable to remove and destroy the first affected leaves and so reduce the spread of the disease. In British Columbia it is recommended that several basal leaves be removed, even if they are not infected, so as to cut down on potential sources of inoculum.

Anthracnose

Caused by *Colletotrichum phomoides* (Sacc.) Chester

This is primarily a disease of ripe fruit. The early symptoms appear as small, sunken spots with dark centers. The spots increase in size, coalesce, and often cover a large area of the fruit, rendering it unfit for market (Fig. 12).

The spores of this fungus are produced in great numbers, and spread infection to sound fruit in containers in transit. Moreover, secondary fungi and bacteria often overrun the anthracnose infection, greatly extending the rot.

Control

1. Rotation is particularly important.
2. Ziram or maneb spray schedules are preferable for anthracnose.
3. Destroy all diseased fruits.
4. Destroy refuse from harvested crop.

Verticillium Wilt

Caused by *Verticillium albo-atrum* Reinke & Berth

The fungus responsible for this disease inhabits the soil and gains entrance to tomato plants through the roots. From the roots it advances through the woody tissue, where it causes a brown discoloration, and spreads into the stem, where defoliation takes place from the base upwards. Affected plants wilt and often die (Fig. 5) though they may survive in an unthrifty condition. The disease is favored by low soil temperatures and poorly drained locations.

Verticillium also attacks potatoes, peppers, eggplants, strawberries, cucumbers, squash, raspberries, and other crops, hence it is essential to avoid such crops in the rotation.

This disease has been destructive in the interior of British Columbia and an active breeding program is in progress at Summerland to develop resistant varieties suitable to that region.

Control

1. In the field, good sanitary measures, such as destruction of diseased tomato vines, along with a 4- to 5-year rotation of crops (avoiding potatoes, eggplants, peppers, etc.) will generally be sufficient to prevent any serious outbreak or development of the disease.

2. In the greenhouse, sterilization of the soil will satisfactorily control this wilt.

3. A relatively high soil temperature (70°-80°F) will effectively check Verticillium wilt.

4. Tomato varieties vary in susceptibility to wilt. Some such as Earliana, Valiant, Clark's Early, and Gem are very susceptible; others such as Longred, Stokesdale 4, and Wisconsin 55 are partially resistant.

Fusarium Wilt

Caused by *Fusarium oxysporum* Schlecht. f. *lycopersici* (Sacc.) Snyder & Hansen

This fungus also is soil borne and gains entrance to the plant through the roots. The fungus grows up through the woody tissue, producing toxic substances that cause the plant to yellow, wilt, and die. The woody tissues of the stems of affected plants show a brown discoloration. Fusarium wilt is favored by high temperatures, and accordingly is a minor disease in Canada.

Seedlings, when grown in infested soil may contract the disease, but often do not show it until after they have been transplanted. In this way, the disease may be transferred to the field.

Control

1. Grow resistant varieties.
2. Practice a long rotation.

Buckeye Rot

Caused by *Phytophthora parasitica* Dastur

Although the most common symptom of this disease, and the one from which the name is derived, is seen on the fruit, buckeye rot may also produce lesions on the stems and leaves, as well as a damping-off of seedlings. Seedlings may be killed either before or shortly after emergence. Stem girdling or collar rot may occur on seedlings or mature plants. Leaf symptoms appear as irregular brown necrotic lesions on the lower leaves. Either green or ripe fruit, especially when in contact with the soil, may become infected through the uninjured skin. A small, grayish brown spot first appears. It enlarges to form concentric rings as the rot increases (Fig. 7). The rot, which is leathery in texture usually affects the fruit to a considerable depth.

Control

1. Sterilize greenhouse soil.
2. Plant on well-drained soil.
3. Spray with bordeaux or a fixed copper.

Phoma Rot

Caused by *Phoma destructiva* Plowr.

This disease is rather unimportant in Canada, but as it is found occasionally a brief description is included here. The disease affects the fruit. It produces large, black, sunken areas in which numerous black 'pimples', the fruiting bodies of the causal fungus, are readily seen in the center of the affected tissue (Fig. 8). Infection on fruit occurs through wounds, growth cracks, and stem scars. On the leaves brown to black spots develop, and dark areas may occur on the stems.

Phoma rot has been troublesome on several occasions in Nova Scotia on mature green tomatoes stored for ripening.

Control

Special control measures are unnecessary, especially if a crop rotation is followed, the seed disinfected, and sanitary measures practiced.

Botrytis Ring Spot and Watery Rot

Caused by *Botrytis cinerea* Pers.

This disease is found on indoor and field tomatoes when atmospheric humidity is high, and appears on the fruit as a ring mark, with a brownish puncture in the center. On green fruits, the ring may be pale green or silvery, with the tissue inside the ring generally of a paler green color. On ripe fruit, the rings are generally yellow (Fig. 9).

This same fungus is also capable of producing a soft rot of the leaves, petioles, and fruit (Fig. 10) especially under humid greenhouse conditions. Infection occurs through injuries or cracks on the fruit and may cause considerable damage.

Control

In the greenhouse, prevent undue humidity. In Ontario there is no need of preventive measures in the field, since this disease is uncommon and rarely causes unmarketable fruit. In Nova Scotia it is a more important disease and in 1956 was the major cause of rotten fruits in the field. A split ziram and bordeaux program was the only one that gave any control.

Nail Head Spot

Caused by *Alternaria tomato* (Cooke) Weber

This disease is similar in many respects to early blight, with which it may be confused, but the symptoms on the fruit, hard scablike spots, are charactistic. The spots are dark brown and usually small, with the discoloration extending beneath the spot into the flesh of the fruit (Fig. 11). Like early blight, it causes leaf spot and defoliation.

Control

Practise crop rotation and sanitation. In severe cases spray with a fixed copper fungicide.

Basal Rot

Caused by an unidentified fungus

This disease, though not prevalent, has been observed in greenhouses in Ontario and may cause as much as a 50 per cent reduction in crop. Infection is confined to the base of the stalk and to the root system which is considerably reduced in size. In affected plants most small roots are entirely rotted, while many of the larger ones are either partly or wholly brown, and frequently considerably swollen; the cortical tissues are rough and cracked (Fig. 13). This root infection results in leaf chlorosis and defoliation of the plant from the base upwards.

Control

The disease can be controlled by soil sterilization.

Root Rot

Caused by *Colletotrichum atramentarium* (Berk. & Br.) Taubenh.

During the past 10 years this disease has appeared sporadically in greenhouse tomatoes in southern Ontario. Affected plants wilt and the root system is greatly reduced. The cortex of older roots is cracked and loose upon the stele, while the younger roots are brown, shortened, and distorted.

Control

This root rot can be controlled by soil sterilization with steam. Satisfactory results have also been obtained with Dowfume MC-2 (methyl bromide 97.5 per cent, chloropicrin 2.0 per cent) at the rate of 4 lb. per 100 cu. ft. of soil.

Bacterial Diseases

Bacterial Canker

Caused by *Corynebacterium michiganense* (E. F. Smith) Jens.

This disease was first reported in Manitoba. In 1924 it was found in the dry belt of British Columbia and since that time it has been present there in

some degree in individual fields. It is uncommon in the rest of Canada. It can be most destructive and growers should become acquainted with its symptoms.

The disease may be identified by a characteristic sudden wilting and rolling of the leaves. The wilting first develops on one side and then extends to the other side. Shoots wilt next. Tissues of petiole and stem collapse and in so doing may expose light-colored cankers. On the fruit the disease produces small round tan-colored spots having a light marking, the so-called 'birds-eye' stage (Fig. 14). Within the fruit the tissue and even the seeds become discolored.

Control

Since the bacteria are carried on and in the seed, and are found in the soil, growers should observe the following advice:

1. Use disease-free seed. Seed may be freed from contamination by fermenting the crushed pulp for 72 hours at room temperature or by treating the seed with technical acetic acid 36 per cent, 1 fluid oz. to 5 pints of water for 24 hours at 65° to 70°F.

2. Keep seedbeds clean. Use sterilized soil.

3. Practice as long a rotation as possible, at least 4 years.

Bacterial Spot

Caused by *Xanthomonas vesicatoria* (Doidge) Dowson

This disease attacks leaves, stems, and fruit, though the most conspicuous spots are on the fruit. On the leaves and stems the infections are small dark spots with a greasy appearance. On the fruit, the spots enlarge to form rough, scabby, dark-colored lesions, in the center of which numerous cracks may occur (Fig. 15). Spread and infection occur during heavy driving rains. The disease also attacks peppers, producing lesions on the fruit and leaves, similar to those on tomato.

Bacterial spot, though rare in Ontario, has on occasion been destructive.

Control

The chief measures of control are seed treatment and rotation of crops in seedbed and field.

1. Treat seed with seed protectant such as Ceresan.

2. Sow the treated seed in sterilized soil.

3. Avoid peppers in the rotation.

Nematodes

Root Knot

Caused by *Meloidogyne* spp. (Goeldi 1887) Chitwood 1949

Root knot is caused by a minute eelworm or nematode that lives in the soil and attacks the roots of such plants as tomatoes, tobacco, and cucumber. Due to the deep freezing of soils in northern climates this disease is generally of minor importance out of doors, though losses may occur under greenhouse conditions.

The disease is readily identified by the distinctive galls formed on the roots (Fig. 16). Aboveground symptoms are pale foliage, unthrifty growth, and wilt, especially in hot, dry weather.

Control

1. Seedlings and transplants should be grown in sterilized soil.

2. Tomatoes should not be grown in fields known to be infested with nematodes.

3. Transplants from an infested seedbed should be discarded.

4. In greenhouses and plant beds, sterilization by steam or by chemical nematocides gives good control.

Virus Diseases

Tomatoes are subject to at least three mosaic diseases: green mosaic, yellow or aucuba mosaic, and cucumber mosaic. In addition, potato mottle mosaic may infect tomatoes. Two other virus diseases, spotted wilt and streak, also attack tomatoes. In British Columbia another virus disease, tomato yellows, is of considerable importance.

Though the nature of a virus is as yet imperfectly understood, it is known that it can spread rapidly and permeate the sap in all parts of a plant.

It should be clearly understood that most of these diseases, especially the mosaic diseases, are so contagious that they can be spread easily by workmen who handle or brush against diseased plants and then pass to healthy ones, as in such operations as tying, suckering, cultivating, and harvesting. The mosaics, streaks, and spotted wilt are also spread by certain insects, which, in the course of feeding, pass from diseased to healthy plants. Tomato yellows, however, is not transferred during cultural operations but is dependent on leaf hoppers for its transfer.

Common or Green Tomato Mosaic (Tobacco Mosaic Virus)

This disease is widespread, and accordingly is well known to most growers. Its main symptom is a light- to dark-green mottling of the leaves (Fig. 19). Affected leaves are usually distorted, puckered, and smaller than normal, while the plant as a whole is reduced in size, pale, and spindly.

Aucuba Tomato Mosaic (Tobacco Mosaic Virus, Yellow Strain)

This mosaic is similar in many respects to common tomato mosaic, but differs from it in that the mottling is brilliant yellow to yellow green, and the fruit, as well as the foliage, often becomes mottled.

Potato Mottle Mosaic (Potato X Virus)

Tomatoes, particularly if grown on soil that has previously produced a potato crop, or if grown near potatoes, may become infected with a potato virus that produces a fine, often indistinct, mottle, due to pale yellow areas appearing between the veins. Small, brown, dead spots often accompany this mottling. Tomatoes thus affected do not show pronounced mottling, distortion of leaf tissue, or stunting of plant as a whole.

Fern-leaf of Tomato (Cucumber Mosaic Virus)

On tomato the virus of cucumber mosaic produces narrow, spindly, leaves with excessive indentations, accompanied by mottling. In severe cases this spindliness is so pronounced that a 'shoe string' leaf is produced (Fig. 20).

Streak (Tobacco Mosaic Virus or Tobacco Mosaic Virus and Potato X Virus)

There are at least two types of streak, one caused by a single virus, and the other the result of infection by a mixture of viruses. Of these, the latter,

though less common, is more virulent. Under Ontario conditions mixed-virus streak is generally the result of infection by potato virus X and certain strains of tobacco mosaic virus.

The symptoms of streak, whether of the single-virus or of the mixed-virus type, consist of mottling with severe distortion of foliage and stunting of growth, accompanied by pronounced necrotic lesions (dead areas) on leaf, stalk, petiole, or fruit (Fig. 21). In the case of single-virus streak the amount of necrosis may range from negligible to severe, but with mixed-virus streak, necrosis is always present, and is often so severe that affected plants produce little marketable fruit.

Spotted Wilt (Spotted Wilt Virus)

This disease, though rather uncommon in Canada, has been reported in several provinces. The outstanding symptom is a bronzing of young leaves, followed by severe stunting and cessation of growth. The bronzing may take the form of isolated spots or may cover most or all of the leaf surface (Fig. 22). The intensity of the bronzing varies from an inconspicuous green-brown glaze to a distinct dark brown to almost black glazed area. Bronzed leaves usually roll inward and affected areas often become necrotic.

Tomato Yellows (Sugar Beet Curly-top Virus)

In some seasons severe outbreaks of tomato yellows have occurred in southern British Columbia. The severity varies with the season; when infection is severe, 30 per cent or more of the crop may be lost. The disease is widespread throughout the Pacific coast region extending from British Columbia to Mexico. In some of these districts, the losses sustained have been as high as 90 per cent of the crop, and in many it is the limiting factor in tomato production.

Diseased plants are readily distinguishable since they are rigid, with stiff brittle leaves that have a marked tendency to roll and droop slightly. No wilting occurs. The veins are generally purplish and the normal green color of the leaf gradually changes to a sulphur yellow. The plant ceases to grow, and the fruit already formed does not enlarge. Eventually the plant turns brown and dies. The disease runs its course in from one to two weeks. Affected plants sometimes show signs of recovery, but rarely do they become normal again. An examination of the root system shows the fine rootlets to be brown and decayed. The outer tissue may be easily rubbed off between the fingers, leaving the central woody core. Careful surveys and field observations, made by the U.S. Bureau of Plant Industry, have shown that conditions that favor a high evaporation rate likewise favor the development of yellows.

Since this disease is caused by the same virus that causes curly top of beets and is transmitted from beets to tomatoes by leaf hoppers, these two crops should always be well separated.

Control of Virus Diseases

1. Select seed from healthy plants, or use seed 6 months to 1 year old. Fresh seed may carry the virus of tomato mosaic.

2. Seed and transplants should be grown in sterilized soil.

3. The all-too-common practice of starting new seedlings in a section of a house that is at the same time devoted to the growing of a tomato crop, is not recommended. It is preferable to grow the new seedlings in a house where there are no tomatoes.

4. Moreover the tomato mosaic virus may spread from such plants as petunia, snapdragon, spinach, pepper, eggplant, potato, tobacco, and certain other plants. Therefore tomato seedlings and transplants should not be grown in close proximity to such plants. This is especially true if tomato seedlings are grown under glass in frames or houses containing many different kinds of plants.

5. It has been demonstrated at the St. Catharines laboratory and elsewhere, that most brands of smoking and chewing tobacco contain the virus of tomato mosaic in a viable state, and that it may adhere to the workmen's fingers and be spread, by contact, to tomato plants during such cultural operations as pruning, tying and so forth. Therefore, while working among tomato plants, workers should not smoke or use tobacco in any form. Its use is especially to be avoided during weeding, pricking-off and transplanting. As an added precaution the hands should be washed repeatedly with soap and water.

6. All mosaic or streak plants observed in the seedbed or flats should be carefully removed and destroyed. Plants infected with mosaic or streak should never be transplanted.

7. Rotate tomatoes with some other crop.

8. After the seedlings have been transplanted to their permanent location, they should be inspected frequently for the presence of virus diseases. All affected plants should be rogued and destroyed. Roguing is of value *only* if done early when infected plants are few in number. When doing this, avoid touching the healthy plants.

9. Many different weeds may harbor the mosaic disease, and therefore weeds should not be permitted in or near the plant bed or greenhouse.

10. In view of the fact that potato and cucumber mosaics pass readily to tomato, it is advisable not to grow these crops near tomatoes. This recommendation is important because these viruses, in conjunction with tomato mosaic, produce a severe form of tomato streak. If it is necessary to work among potatoes or cucumbers, as well as tomatoes, always wash the hands thoroughly before passing from one crop to the other.

These additional measures apply mainly to greenhouse crops:

1. The hands (also knives and other implements used during the various cultural operations) should always be thoroughly washed immediately after diseased plants have been handled, particularly during the seedling and early transplant stages of the crop.

2. During cultural operations (pruning, tying, etc.) treat all healthy plants first, leaving mosaic or streak plants till the last.

3. In view of the spread by insects, keep the insect population as low as possible by frequent fumigation.

4. Unless it is carefully handled, the tobacco refuse used for fumigation purposes may be a possible source of infection of the crop. The ashes and unburned trash should not be mixed with the soil but should be removed from the house. The hands should be washed after handling the tobacco, and care should be taken to see that none of the tobacco is left lying around on paths, beds, or benches.

5. Do not use tobacco trash as a fertilizer in tomato beds unless it is first sterilized. The use of unsterilized trash may be responsible for wholesale infection of the tomato crop.

The virus causing common tomato mosaic may remain alive in the soil for some weeks after the crop has been harvested. At St. Catharines it has been found to be still viable after three months.

Diseases of Doubtful Cause

Blotchy Ripening of Fruits

In Ontario blotchy ripening (Fig. 18) is more common in the greenhouse crops, but is also found in the field, especially on staked tomatoes. In Nova Scotia, however, the reverse is true; there, blotchy ripening is rarely encountered in the greenhouse. Also, in contrast, internal browning of the vascular tissues is associated with blotchy ripening in Nova Scotia while in Ontario tissue browning is uncommon. In England, where this problem has received considerable attention, internal browning is only sometimes present. In a form of blotchy ripening called 'waxy patch', which is considered to be a severe form of the disorder, necrosis of the vascular tissues is invariably present.

The cause of blotchy ripening is imperfectly understood. A form of uneven ripening may be caused by the tomato mosaic virus, and this virus can be isolated readily from affected fruits, but on the other hand repeated isolations from similarly affected fruits have given negative results. Therefore, though some blotchy ripening may be due to the tomato mosaic virus, apparently some is not. The cause of the latter cases is not known. It has been reported that there is a greater incidence of this disease in potash-starved plants. Light intensity also seems to be a factor, there being a significant negative correlation between hours of sunshine and incidence of blotchy ripening.

Internal Browning of Fruits

Several types of internal browning of tomato fruits have been reported. In Florida internal browning is largely confined to the vascular tissues while in New Jersey all parts of the fruit except the more succulent portions between the seed cavities may be involved. In Texas the core as well as the vascular tissues may show browning. In Ontario internal browning is not necessarily confined to the vascular tissues, and there may be no external symptoms, though some pitting of the surface may occur. In contrast, in Nova Scotia internal browning is generally associated with blotchy ripening. Whether or not these different manifestations of internal browning are due to one or more causes has yet to be ascertained. It has been shown recently that a type of internal browning develops as a 'shock' symptom on fruits when plants become infected by certain strains of the tobacco mosaic virus as the fruit matures.

Nonparasitic Diseases

Oedema

Oedema is apparent as numerous small swellings on veins, midribs, petioles and stems. The swellings at first are frost-white and confined beneath the epidermis. Later the epidermis is ruptured and the spots become yellowish brown in color, and corky in appearance. These wartlike swellings may occur singly or so close together that they form complete ridges of variously shaped irregular, raised areas.

This trouble is due to improper greenhouse environment, such as overheating, overwatering, and lack of ventilation, resulting in the atmosphere above the plants being so moisture-laden that the plants cannot give off sufficient water as vapor. In order to avoid, or overcome, this trouble, the grower should see that watering and heating are carefully regulated.

Blossom-End Rot

Blossom-end rot is associated with environmental conditions and is not caused by a disease-producing organism.

It is confined to the blossom end of the fruit and appears as a dark, sunken, dead area. The rot is dry and firm (Fig. 17) though secondary organisms often invade this tissue and produce a soft rot.

Though the cause of the disease is imperfectly understood, it usually follows drought conditions or irregular water supply. Excessive moisture followed by drought favors the trouble and it is often more prevalent on sandy and on freshly manured soils. Usually blossom-end rot does not develop even under continued dry weather conditions, if there is sufficient soil moisture to maintain steady, if unthrifty, growth. Recent research shows that deficiency of calcium is a fundamental cause of blossom-end rot in Florida where most sandy soils do not contain enough potentially soluble calcium. Under such conditions excess total salts and a low calcium ratio favor this disease.

Control

In greenhouse soils where calcium is generally in sufficient supply regularity in watering should control this disease satisfactorily.

In the field where calcium may at times be deficient spraying with calcium chloride, 4 lb. to 100 gal. water per acre, when the disease first appears should be beneficial. The number of applications will depend on the balance of calcium in the soil and therefore no general spray schedule can be recommended. In Florida twice-weekly applications during critical periods have given satisfactory control.

Walnut Wilt

If tomatoes are planted within 50 ft. of walnut trees or in soil from which walnut trees have been removed the tomatoes may wilt and die. This walnut wilt is caused by a toxin called juglone which is secreted from the roots into the soil and kills tomato plants. This toxin remains in the soil for several years after the trees have been removed.

Control

Do not set tomato plants near walnut trees nor on land from which black walnuts have been removed.

2,4-D Injury

Tomato plants at any stage of growth are very susceptible to 2,4-D injury. Even minute amounts of 2,4-D drift may cause severe distortion of tip leaves, bending and twisting of new growth, and 'shoe-string' type leaves with veins prominent and 'cleared'. The distortion and abnormal venation are diagnostic symptoms.

Because of the extreme susceptibility of tomatoes to 2,4-D this chemical and related ones such as 2,4,5-T should not be used for weed control in tomato fields, or even in the vicinity of tomatoes. Experience has shown that 2,4-D drift in imperceptible amounts may be carried considerable distances and still affect tomatoes and other susceptible crops. Many cases of 2,4-D injury to tomatoes have been traced to drift from herbicides used in roadside and fencerow spraying for weed control. Since it is most difficult to free spray equipment from all traces of 2,4-D, a sprayer used for weed control should not be used for spraying tomatoes unless it is meticulously cleaned. The preferable method is to have a sprayer solely for weed control.

Sunscald

When fruits are exposed to intense sunlight sunscald may result. This is especially true when foliage is sparse because of the habit of the variety or

from defoliation of leaves by diseases such as leaf spot, early blight, or Verticillium wilt. The exposed side of the fruit shows yellow to white blister-like areas.

Nonparasitic Leaf Roll on Staked Tomatoes

Though varying degrees of rolling of tomato leaves may be associated with different parasitic diseases, a nonparasitic leaf rolling is invariably encountered on staked tomatoes. The lower leaves roll upward until the margins touch or overlap. Such leaves are tough and leathery. This severe rolling is generally considered to be a reaction on the part of the plant to the excessive pruning in this type of culture.

Lightning

Lightning injury to field tomatoes and other crops though uncommon is encountered almost annually. The injury occurs generally in a circular to elliptical area some 50 to 75 ft. in diameter, the plants in the center being killed while those towards the margin of the area are less severely damaged. The stems, branches and petioles shrivel and the pith collapses.

Acknowledgment

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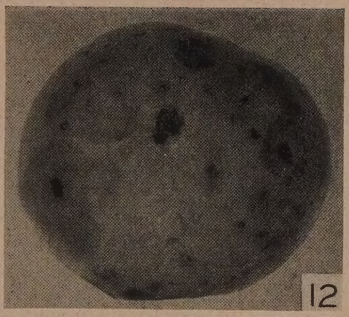
PLATE 1

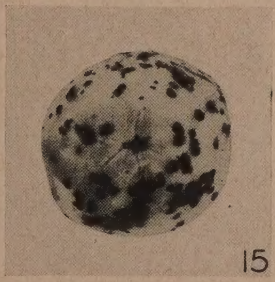
FIG. 1.—Collar rot (left) showing hollow stem, and Botrytis sp. (right) growing on stalk.
FIG. 2.—Leaf spot on stem and leaf.
FIG. 3.—Early blight (greatly enlarged). Note concentric rings in lesions.
Fig. 4.—Leaf mold on underside of leaf.

PLATE 2

FIG. 5.—Verticillium wilt; diseased plant on left and healthy plants on right.
FIG. 6.—Late blight on underside of leaf.
FIG. 7.—Buckeye rot. Note concentric rings.
Fig. 8.—Phoma rot. Note the small black fruiting bodies in center of lesion.
FIG. 9.—Botrytis ring spot.
FIG. 10.—Botrytis watery rot showing the fungus growing on fruit.

PLATE 3





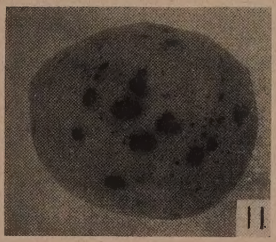


FIG. 11.—Nail head spot.
FIG. 12.—Anthracnose.
FIG. 13.—Basal rot. Note enlarged cracked lesions on roots.
FIG. 14.—Bacterial canker.
FIG. 15.—Bacterial spot.
FIG. 16.—Nematode galls on roots.

PLATE 4

Fig. 17.—Blossom-end rot.
FIG. 18.—Blotchy ripening.
FIG. 19.—Tomato mosaic.
FIG. 20.—Symptoms caused by cucumber mosaic virus.
FIG. 21.—Streak on leaf and stalk.
FIG. 22.—Spotted wilt. Note ring spotting.

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